FURTHER STUDIES ON THE ACTIVITIES OF ARANEADS, II.

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The following observations were made at Woods Hole, Mass., during the Summer of 1909. For the identification of certain species my thanks are due to Mr. Nathan Banks and to Prof. G. W. Peckham.

1. The Process of Sperm-Induction.

It will be recalled that Lister in 1678 discovered that the male spider in coition applies his pedipalpal bulb to the genital aperture of the female; and that Menge in 1843 found that the male charges his palpi by depositing a drop of sperm upon a specially constructed inclined sheeting, and then touching this drop with his palpal organs. The latter process, termed by me sperm-induction, was seen by Menge in *Linyphia, Agelena, Tapinopa* and *Micrommata;* by Blackwall (1863) in *Agelena;* by Ausserer (1867) in *Dictyna* and *Linyphia;* by Bertkau (1875, 1876) in *Philoica, Linyphia* and *Clubiona;* by Westberg (1900) in *Linyphia;* and by me (1903) in *Tegenaria, Theridium, Dictyna* and two species of *Lycosa.* The exact literature references are given in my paper of 1903;[1] consequently they need not be repeated here. The process has been observed, accordingly, in only ten genera, representatives of six families, so that the following new observations on representatives of two other families are not without interest. It is difficult to see this act, and success is obtained only by long continued watching of spiders kept in cages.

The first species to be described is the common large Attid, *Phidippus purpuratus* K. One male, No. 1524, was placed on 20 June in a cage with two females, and copulated the same day with one of them. The next day he avoided his mates, and at 5.32 P.M. was seen spinning a small sheeting, from the floor to the side of the cage and inclined at 45°; four minutes later he deposited a minute drop of sperm upon it, barely visible to the naked eye; then extending his body over the sheeting, reached his palpi downward and backward, applying them in alternation against the drop; the palpal organs were pressed, not against

[1] Studies on the Habits of Spiders, particularly those of the Mating Period, *Proc. Acad. Nat. Sci., Philadelphia,* LV, 1903, p. 59.

the free surface of the drop, but against the reverse surface of the sheeting. At 5.43 he was interrupted by a feeding female, and he moved away from the sperm-bridge with a minute droplet of sperm at the apex of his right palpus and another left on the bridge. Another ♂, No. 1508, of the same species, copulated on 17 June, and the day following was observed at the close of the sperm-induction at 7.10 P.M.; he had spun from one vertical wall of the cage to the other, in an angle, a narrow transverse ribbon of silk, with its flattened surface in the vertical plane; against this he placed his ventral surface, with his cephalic end elevated and the abdomen flexed, applying his palpi gently and alternately against that surface of the sperm-bridge directed away from his body. He ceased at 7.15, went into a corner of the cage and there rested quietly. With a hand lens a thin film of sperm could be seen upon the bridge, and next day the sperm was found with the aid of the compound microscope. The same male (1508) copulated on 20 June in the morning, and at 6.20 P.M. was found forming another sperm-bridge like the first; at 6.24 he dropped a minute globule of sperm upon it, and then applied his palpi in alternation to it as in the preceding cases; this palpal application lasted six minutes, when he turned away, but he seemed to be prematurely interrupted by the movements of a grasshopper.

The other case was that of a male of *Drassus neglectus* (Keys.), No. 1527. He and a ♀, No. 1528, were caught together in a closed nest on 17 June, placed in a cage, and there he built a beautiful and spacious saccular nest around both. On 23 June, at 11.37 A.M., he was observed in nearly vertical position within this nest, moving the ventral surface of his abdomen repeatedly against an inclined sperm bridge built against the inner surface of the nest and with its upper edge free. In half a minute he discharged a droplet of sperm upon it, then lowered his body to bring his jaws about on a level with the upper margin of the bridge, reached his palpi over this free margin and rubbed them gently many times against the reverse side of the sperm-bridge. One palpal bulb was thus rubbed at a time, then raised in the air while the other was rubbed. The application of the palpi continued for 17 minutes.

In all the cases so far described there is quite general uniformity in the process of sperm-induction; a special sperm-bridge is spun, a droplet of sperm placed upon it on the side next the spider's body, then the palpi applied alternately against the opposite side. The cephalothoracal end is always raised. In the case of *Phidippus*, No. 1508, this act was seen twice, each time after observed copulation,

and since the process must have occurred before the first coition, this particular individual must have accomplished the process at least three times. But I have seen no evidence that a replenishing of the palpal organ is necessary after each copulation; the charging of them is generally sufficient for a number of copulations, the number probably varying with their duration.

2. The Atypical Habits of Ariadna.

In all cases of egg-laying so far known in Araneads the process is strangely uniform even though the finished cocoons may differ greatly in form and texture. A base is first spun, a drop of viscid secretion emitted from the genital aperture upon it, the eggs discharged into this drop, then a cover spun around the egg mass. I have watched the details of this process in so many instances, and in such a variety of forms (Avicullariids, Thomisids, Drassids, Lycosids, Epeirids, Theridiids, Sicariids, Agelénids, Dictynids, Attids, Filistatids, Pisaurids), that I had come to believe it was the universal process in spiders. But in the interesting Dysderid *Ariadna* (*Pylarus*) *bicolor* (Hentz) a form was found that builds no cocoon at all, and that lays its eggs in a drop of salivary secretion.

This species is common in certain open fields at Woods Hole, where it makes its nest on the under side of stones. No adult males were found from early in June until the middle of September, when I ceased my observations. It constructs a firm and rather tough silken tube, up to nearly three inches in length in the case of large individuals, quite viscid, so that foreign objects readily adhere to its outer surface. Generally the tube has a single opening that flares outwards something like a funnel, and has been figured and described by McCook[2], but sometimes there is an opening at each end, and this is not infrequent in the case of nests spun in captivity. Kept in artificial cages the spiders sometimes wander out of their nests at night; but for the most part they remain within them, at the enlarged entrance, with the three anterior pairs of legs extended forwards ready to seize prey and drag it into the nest,—as well described by Hentz.[3] Frequently a colony of them is found beneath a single stone, and then their nests are sometimes contiguous with each other and with those of *Phidippus* and *Drassus;* but they are not strictly colonial, for they are cannibals whenever an opportunity offers. In captivity they appear to spin

[2] *American Spiders and Their Spinning Work*, Vol. II, Philadelphia, 1890.
[3] *The Spiders of the United States*, ed. Burgess, Boston, 1875.

usually between midnight and dawn. A nest is the product of several days of labor and is probably added to and lengthened from time to time. The spiders can barely walk upon smooth glass, even when horizontal. They feed within their nests and remove the remains of the food outside. They exhibit death-feigning to a considerable degree.

To observe the egg-laying a number of individuals were isolated in small vials; groups of others were also placed in large cages each made of two glass panes 12 x 8 inches, separated by a wooden frame $\frac{7}{8}$ inch thick; food could be introduced and air provided by holes in the wooden frame.

No egg masses were found in wild nests before 20 June, and the individuals observed had not oviposited.

The oviposition is carried out within the nest. The entire process was seen in the case of two individuals, and parts of it in other instances. It may be described from the case of 1534 B, caught and placed in a cage on 26 June. On 4 July she spent the afternoon spinning against the inner surface of her nest, thickening it, but making no special cocoon base. At 6 P.M. she became quiet except for a movement of the palpi against the jaws that I first interpreted as a cleaning operation, but watching her attentively with a hand lens, I saw that both palpi were flexed, their free ends rubbing her chelicera rather slowly but regularly, and at 6.11 a minute drop of fluid could be seen at the apices of the chelicera. The two palpi steadily continued to rub the jaws, the chelicera and maxillæ moving backwards and forwards as well as opening and closing, and the drop slowly increased in volume by the addition to it of droplets that merged with it; the drop was viscid, as shown by its form, and evidently issued from the vicinity of the mouth. Thus the drop slowly grew in size, and was slowly pushed caudad beneath her cephalothorax, until it extended like an ovate pearl from the mouth back to the anterior border of the abdomen; it was transparent at the periphery, but more opaque in the centre, while the newly issuing droplets, to be added to it, were all transparent. Consequently the opacity of the interior may have been due to a change in consistency. This process lasted continuously from 6.11 to 6.37, then the abdomen was quickly flexed downward slightly, and the viscid drop suddenly clouded—due to successive discharge of the eggs into it. This discharge of the eggs occupied almost 3 minutes. The spider then commenced to sway her body slowly back and forth over the egg mass in the drop, and continued to do so for almost an hour. This movement was the attempt to free her chelicera and the ventral surface of her cephalothorax from the surface of the viscid drop. The

spider was horizontal, dorsum uppermost, the feet fixed against the inner surface of the nest.

Another female (1534 C) occupied the time from 7.45–8.16 P.M. to produce the viscid drop. Another one (1534 D) worked from 5.54–6.32 P.M. to make the drop, occupied 5 minutes in the discharge of the eggs into it, then took more than an hour to free herself from it.

In not a single instance of the egg masses laid in captivity (13 cases) was either a special base spun for the egg mass or a cover spun around it. The inner surface of the nest serves as a base, there is no silken cover, but the eggs are held together insecurely by the hardening of the salivary drop; insecurely, because the egg mass readily rolls out of the nest, and the eggs are easily shaken apart by light handling.

It remains to be determined just what glands furnish the viscid drop into which the eggs are discharged. It may be composed of a secretion issuing from the mouth, or from the unpaired gland of the rostrum or the salivary glands of the maxillary plates.[4]

Of the 13 timed egg masses deposited in captivity, 8 were made between 6 and 8 P.M., 3 about 5 P.M., and only 1 in the early morning.

The time from egg laying to hatching is unusually long in this species, at least for eggs laid in the summer.[5] If we consider as hatching the time when the spiderlings first commence locomotion, the 8 timed cases in *Ariadna* presented time intervals between egg laying (in last week of June and first week of July) and hatching of from 63–70 days.

Not more than one egg mass was made by any of my captives, and to test whether any individuals may oviposit twice in the same year I caught on 22 August 9 females, each from a nest with a single mass of eggs or young, and kept them together in a large cage until 12 September, but no further eggs were laid. Since the first eggs are laid after the middle of June and do not hatch until September, and since the middle of September brings in cooler weather, it seems probable that they oviposit only once in a year—a condition rare in spiders.

It is general, though not invariable, that at the time of oviposition the spider closes the entrance to the nest by spinning over it, and all my captives that had so closed their nests kept them sealed until after the young had hatched. How long the young remain in the nest after hatching was not determined. But wild spiders, in natural

[4] On the glands in the vicinity of the mouth cf. especially: Plateau, 1877, Recherches sur la structure de l'appareil digestif, etc., chez les Aranéides dipneumones, *Bull. Acad. Roy. Belg.* (2), 44; and Bertkau, 1884, Verdauungsapparat der Spinnen, *Correspondenzbl. Naturh. Ver. preuss. Rheinlande.*

[5] In certain Epeirids, whose eggs are laid in the autumn, hatching does not take place until the following spring, the cold arresting the development.

conditions, always seem to have an opening to the nest even when the eggs or young are in it.

Ariadna thus resembles its congener *Dysdera* in having no special cocoon for the eggs,[6] though both build nests. This would suggest that the nest may be a racially older structure than the cocoon, and that the Dysderids may be one of the most primitive groups of living araneads.[7] The use of a mouth or salivary secretion to agglutinate the eggs has never been seen before in spiders, though Bertkau (1884, *l. c.*) has described such a process for the acarine *Ixodes*.

3. The Habits of Pisaurina.

The Pisauridæ closely resembles the Lycosidæ in structure, but differ from them in being arboreal during the cocooning season rather than terrestrial, and in carrying the cocoon by the chelicera and not suspended from the spinnerets.

The fullest account of the habits of any Pisaurid is given for the European *Dolomedes fimbriatus* Clerk by Pappenheim.[8] He saw the cocooning only once; a spider spun a funnel-shaped cylinder of silk, the closed roof of which was the upper surface of the glass cage; "in the cavity so bounded the eggs were laid. . . . . Immediately after the oviposition the cocoon, that was at first cylindrical, took on gradually the form of a hollow sphere from its continuous working by the extremities and the abdomen." Pappenheim does not make it clear whether he saw the actual egg discharge and cocooning, or only the finishing of the cocoon within an infundibular nest, but apparently he saw only the latter. No other naturalist has described the cocoon-making for any member of the family.

Pisaurina mira (Walck.), more generally known as *Ocyale* (*Micrommata*) *undata* (Hentz), is unusually abundant in the woodland at Woods Hole, even at places far removed from water, though those kept in cages require water daily. Males are very rare (I have seen only one, from the collection of Mr. Emerton), and not a single one was found during the past summer. The large, white, globular cocoons of this species are well known, and so are the nests that the mother spins around the young at the time of hatching, and have been sufficiently

[6] According to Simon's statement concerning *Dysdera* in his *Histoire Naturelle des Araignées*, 2d ed., Paris, 1892, T. I, p. 311.

[7] Reasons have been recently presented by me showing that the tetrapneumonous spiders (Theraphosæ) are not primitive: On the Spinnerets, etc., *Proc. Acad. Nat. Sci. Philadelphia*, 1909.

[8] Beiträge zur Kenntnis der Entwicklungsgeschichte von Dolomedes fimbriatus Clerck, *Zeit. wiss. Zool.*, 74, 1903.

described by Emerton,[9] McCook (*l. c.*) and myself (1903), and have been figured by the last two. But their method of construction has not yet been described, nor has any reference been made to a curious nest in which the cocoon is placed and which may be called the "cocoon-nest," in distinction from the "progeny-nest."

The Cocoon-nests.—These are found most frequently, as are the progeny-nests, on the poison-ivy (*Rhus toxicodendron*), where three terminal leaves are spun together to serve as a roof. The cocoon-nests are much less frequent than the others, and most of the spiders carrying cocoons in their jaws are not in such nests; therefore, it is probable they are vacated by the spider before the hatching of the young, for I have found the majority of the nests without spiders in them. The wild nests are each an arched or bellied sheeting of silk placed in the shelter of the under side of three poison-ivy leaves, each such sheeting varying in dimensions from 1 x 1¼ inches to about 2 x 2½ inches according to the size of the mother (which varies greatly), and with two or three apertures at its margins. Two of the spiders only of those that formed cocoons in captivity constructed cocoon-nests, and each of them not until three or four days after the cocoon was formed; these two nests were beautiful inverted domes, fastened to the glass roofs of the cages with a wide aperture below of about two inches diameter. The latter two nests were quite unlike the natural cocoon-nests found in the woods, and seemed to represent an attempt on the part of the spider to replace the roofing of ivy-leaves; it was probably a similar construction that Pappenheim observed in the case of *Dolomedes*. The cocoon-nests found in the state of nature are probably receptacles constructed by the spider in which to make her cocoon, and indeed the most heavily pregnant female caught was taken from such a nest.

The Cocooning.—Spiders are found with cocoons in early June, and they construct at least two during the summer. The cocoons vary much in diameter, are held by the mother by her chelicera and pedipalpi and also frequently by one or more pairs of legs, and are at the same time generally fastened by a few lines to the cocoon-nest or to the plant on which she lives. They are rarely left by the mother before the young hatch. Nine females were kept isolated in large glass cages for the observation of the cocooning; six of them made cocoons, all constructed in the early morning hours between midnight and 7 A.M. This particular time of the day is unfortunate for the observer, for after midnight one naturally seeks repose. But in one case a considerable

[9] New England Lycosidæ, *Trans. Connecticut Acad. Sci.*, 1885.

portion of the process was seen, as follows: Female No. 1571 was caught 31 July in a natural cocoon-nest. Placed in a cage she spun some lines that night, and on 2 August spun quite a network of lines from 7.30 P.M. up to 1 A.M., frequently stopping to bite lines that impeded her movements and taking the relatively long period of from several seconds to half a minute to make a line attachment. On 5 August at 3.10 A.M. I found her in the act of beginning the cover to a freshly laid mass of eggs. She had constructed a flat scaffolding of silk, inclined at an angle, extending from a twig to the wall of the cage. The egg mass had been laid upon this scaffolding, and probably only a short time previously, for the eggs were but thinly covered with silk. The cocoon was not regularly circular in outline, but irregularly polygonal, and its diameter was less than the length of the spider. When first seen she was holding its edges with her feet and was applying the thread by raising and lowering the abdominal apex, and this method she pursued throughout, which accounts for the cocoon being loose in texture and with no dense outer layers.[10] When she had accomplished spinning the cover to the eggs the cocoon had the form of a plano-convex lens, quite different from the spherical shape when fully completed. At 3.55 she commenced to free the margins of the cocoon from the scaffolding by biting certain threads, mainly of the lower portion, of the scaffolding, alternating (for 10 minutes) this biting with spinning on the surface so freed. At 4.10 she fastened a line from the cocoon to the roof, then continued her spinning. From 4.20–5.00 she was occupied in again biting the lines that held the cocoon to the scaffolding, finally leaving the cocoon suspended by its upper margin within a freed space. It had now become nearly circular.

The general process of cocooning is thus as described by me for Lycosids, but different in that the upper margin of the cocoon is left attached and suspended until after it is completed (in some cases this attachment is maintained for a couple of days afterward), whereas Lycosids finish their cocoons while held beneath their bodies.

Hatching and Progeny-nests.—Of three cocoons made in confinement (between 31 July and 6 August) and kept to hatching, the young emerged in 25, 26 and 30 days respectively. The mother holds the cocoon until a day or two before the young hatch, then waits until the first young come out before she makes the nest around them; none

[10] It need hardly be recalled that such application of the spinnerets always produces architecture of soft consistency, while sweeping of the spinnerets without elevation produces a firmer and tougher mesh.

of my captives made the progeny-nest before emergence of the young. As the young emerge the mother builds a network of lines around them, she remaining on the outside of the nest, and increases the number of the lines with the number of the young hatching. In this way the progeny-nest, a real nursery, is gradually built around the spiderlings and the empty cocoon, the mother working on it for as much as three days. In natural conditions such nests are placed generally at a height of about two feet above the ground, rarely as high as four feet, most frequently on a terminal branch of poison-ivy or oak, or the frond of a large fern, the leaves closely spun together to form a protecting and hiding roof over the network of lines below. The mother seems to leave the nest and wander off shortly after she has completed it; thus, on 2 August, I found about forty progeny-nests along a path in the woods, and though fully half of them contained young the mother was on the nest or in near vicinity to it in only two cases—and in these two the young were in process of emergence from the cocoon. In the one case timed the young left the nest on the ninth and tenth day after hatching.

The Mother's Abstinence from Food.—These relatively large spiders are remarkably timorous, seeming to fear grasshoppers of a size that much smaller spiders will quickly seize, and this timidity seems to be increased in the periods when they are holding cocoons—possibly because the maternal solicitude inhibits the desire for food, as it certainly impedes the search for it. All my captives drank water eagerly each day, though still holding to the cocoon by the feet, but in most cases refused all insect food until about the time when the young hatch; in most instances they made no attempt whatsoever to grasp insects walking near them. Evidently it is the hunger for food that takes them away so soon from the progeny-nest. The ability to undergo long fasts is well known for the females of a number of species of spiders, while males appear to need food at more frequent intervals—just as they generally require more water.

Effects of Removal of the Cocoon.—Females with cocoons, when caught roughly and separated from their cocoons, will frequently feign death admirably, lying quite limp and suffering handling without moving. No case of death-feigning was seen in any individual holding a cocoon. If the cocoon be returned to them within a few minutes they generally grasp it immediately in their jaws and seek escape. But there may well be individual differences in this behavior. Thus with a pencil I removed the cocoon two inches away from one of my captives; she showed no death-feigning, but walked about feeling for it. When I

pushed it until it touched her she jumped away, and though she soon thereafter felt it once or twice she each time sprang away and remained quiet. I then pushed her gently so that one of her palpi rested on the cocoon; she remained quiet in this position for a quarter of an hour, then suddenly grasped it with her jaws and feet. In this case the maternal instinct did not seem so strong as that of self-protection.

4. Experiments to Determine Whether Lycosid Spiderlings can Emerge Unaided from the Cocoon.

It has previously been shown by me (1903, *l. c.*) that Lycosid mothers bite open the cocoon along the line of the junction of base and cover, so as to allow the young to emerge. The following observations prove conclusively that the young are unable to bite their own way out of the cocoon:

Twenty-nine cocoons were removed from as many females of a small *Pardosa*, found running in a wood, and kept about six weeks on my desk in open bottles out of the direct sunlight. In eleven of these cocoons the young failed to hatch, due either to the handling of the cocoons or to lack of fertilization of the eggs; while in eighteen the young hatched normally, but failed to emerge, died and shrivelled. In two cocoons taken from females of *Lycosa lepida* and kept in the same way the young also hatched, but died within the cocoons.

5. Apparent Mimicry and Stridulation in Certain Drassids.

Geotrecha (*Thargalia*) *bivittata* (Keys.), *G. pinnata* Emerton, and *G. crocata* (Keys.) are found fairly abundantly during the summer running on the ground in cloudy weather, *crocata* more in open fields and the others in shaded places in the woods. The first two resemble rather closely in form and movements the macroergates of a large mound-building ant; and the particular locality at which I found *bivittata* and *pinnata* most abundant was within twenty feet of such an ant nest,—there being found also many wingless nymphs of the hemipteron *Alydus*, which also resemble this ant. This seems to constitute a complex case of mimicry. But when these ants are placed together with individuals of *Geotrecha* they quickly bite and kill the latter, so that the ants are not in any way deceived and there is no myrmecophily.

In defining the genus *Geotrecha* Emerton states, in speaking of the abdomen: "It sometimes has a small, hard patch at the front end which is of the same color as the rest of the back and not easily seen." This I have found in all three species mentioned, where it occurs at

the antero-dorsal aspect of the abdomen and is a thickened chitinous plate, slightly protuberant, of oval form. Now these species all show a peculiar movement of the abdomen, such as I have never seen so pronounced in any other spiders; they raise and lower the abdomen, slightly rotating it on its pedicel, and continue this movement for several seconds at a time. This movement is exhibited generally just when the spider comes to rest after a run, and is exhibited equally by both sexes. An individual frequently rotates the abdomen immediately before starting on a run, on meeting another unexpectedly or on coming into contact with a large living insect. It is sometimes seen when the spider is quietly cleansing itself, but not when the cage is given a sudden rap. The hardened abdominal plate at such times rubs against the posterior border of the cephalothorax; accordingly, it is a stridulation movement. But if any sound is produced it is quite inaudible to the human ear, and if one individual stridulates in the close vicinity of another the latter does not respond by any movement whatsoever and therefore does not appear to be affected by any sound. It is in no way a sexual call, for the male hunts the female and finds her by touch, and neither he nor she stridulate during the mating. The ants they resemble do not show this movement.

This genus then exhibits a good case of stridulation, but if any sound is produced thereby it seems to cause no effect on other individuals and, therefore, is probably not perceived by them. The presence of a stridulation apparatus need not imply the power of hearing in the species concerned, and indeed the studies of Wagner and Pritchett seem to have definitely determined that spiders do not possess hearing—they possess in its place a most acute sense of touch.

These spiders run with perfect ease on smooth glass.

6. Notes on Modes of Copulation.

Phidippus purpuratus K.

The pairing was observed in 26 instances. The male stands over the female, his ventral surface against her dorsal, their heads in opposite directions, their body axes not in the same line, but his bent obliquely toward one side of her abdomen. Only one palpus is inserted at a time, and one alone may be employed through the act, or the two may be alternated one or more times. The female remains motionless. In the cases timed the act lasted less than one hour in 5 instances, and more than one hour in 9 instances, the longest noted being more than $8\frac{3}{4}$ hours continuously. It may occur in the morning (7 cases), afternoon (11 cases), or after 6 P.M. (8 cases). The same pair have bee-

seen to mate in captivity as many as 6 successive times, as the pair ♂ 1500 x ♀ 1501 with copulation on 13, 20, 21 and 28 June, and 18 and 21 July; the same female has been seen to mate with two males, and the same male with two females. In two instances females were seen to copulate after making the first cocoon: thus ♀ 1519 mated with ♂ 1518 on 20 and 21 June, cocooned 29 June, then mated with ♂ 1519 A on 4 July; and ♀ 1521 mated with ♂ 1522 on 26, 27, and 30 June, cocooned 2 July, then mated again 23 July. This repetition of copulation after oviposition is most unusual, for generally in spiders the males die by the time the first cocoons are made. Equally unusual is the fact that heavily pregnant females will receive males as late as four and even two days before oviposition, whereas it is the rule that pregnant females are extremely aggressive towards males (except in *Theridium*). But we shall see a case in *Geotrecha pinnata* of copulation during cocooning. Another unusual incident, though I have described elsewhere similar occurrences in some other species, was that ♂ 1504 copulated with ♀ 1505 and she moulted a few hours afterwards. Early in June males are quite as numerous as the females, and pairs are frequently obtained in the same nest beneath a stone, but males decrease in number during the summer, though I captured two as late as 22 August. The first ♂ caught, No. 1500 on 13 June, was kept continuously in a cage with ♀ 1501, and copulated with her six times (the last time on 21 July), until 12 September; then I killed her, but kept him, and he lived until the end of October. This longevity of a male after the breeding season is without parallel in my experience. In one case a male (1504) after copulating with a slightly smaller female (1505) on 17 June, ate her on 25 June. This is a rare happening among spiders, though McCook (*l. c.*, Vol. II, p. 24) cites similar instances in Epeirids and Agalenids. This male was, however, killed and eaten by another female (1544) on 11 July, so was ♂ 1524 by a gravid ♀ 1525, and ♂ 1502 by ♀ 1503 (after living together for nearly a month). Five other males that were kept with females, and all of which mated with them one or more times, died without being eaten and with little or no evidence of injury; they seemed to have become physically weakened, and one that I gently removed from his mate to use for another experiment expired a few minutes after the removal. Accordingly, in this species, where the males are about as large and strong as the females, it is by no means the rule that the males end by being eaten. The matings observed in captivity took place in almost every instance outside of nests.

Drassus neglectus (Keys).

With regard to this species, common under stones in open fields

Emerton (*l. c.*) states (under the name of *D. saccatus*): "In the early summer a male and female live together in the nest, the female often being immature." During June I found several such pairs, as well as males in separate nests, but after that month found no more males. The copulation was observed in two cases. The first instance concerns ♂ 1510 (an unusually large individual) and ♀ 1511, found in different nests on 7 June and placed in one cage; he was larger than she. The same day copulation was observed from 5.31–5.38 P.M., one palpus applied at a time, the right three times and the left once, each palpus being held in the epigynum for 1–2 minutes, then withdrawn for about a minute, then the same or the other palpus inserted. He left her at 5.42, but returned two minutes later and inserted the left palpus for 15 seconds, then he left her again and she moved away five minutes later. The position of the two was about the same as in *Phidippus*. This pair were observed again in mating attitude at 3.30 P.M., 24 June, 8.10–8.17 P.M., 25 June, and 9.P.M., 29 June; he died (not eaten by his mate) on 4 July. The other instance was that of ♂ 1506 and ♀ 1507 caught in the one nest on 16 June and placed together in a cage. On 23 June, at 9 A.M., I found him copulating with his right palpus; she had moulted within the preceding half hour, was still soft and near her old exuvia. He kept his right palpus inserted for 39 minutes, and when he withdrew it she struggled away from him. But he found her again, at 9.42 inserted the same palpus for a few seconds, again at 9.46 for a minute, and again continuously from 9.48 to 10.25, when I was obliged to leave, and on my return at 11.12 they were separated. Both escaped from the cage before the end of the month.

This instance of mating with a female just at the time of her moulting is interesting, for it gives the timorous male his opportunity while she is helpless. It is probably full-grown males that seek out still immature females and live with them in the same mating nest.

Geotrecha crocata (Keys).

The mating was observed only once, in the case of a female caught 3 August, and a male ten days previously, placed together in a small cage on 4 August. In copulation the male stands over the female, his ventral surface opposed to her dorsal, their body axes obliquely inclined, his head a little to one side of the anterior end of her abdomen. One palpus is inserted at a time. On 4 August they were observed in copulation at 7.58 P.M. (three minutes previously they were separate), and he kept his left palpus inserted for two minutes, the left for nearly two minutes again, the same for one minute, then the right

for a few seconds, when she suddenly rose and he jumped away. She moved slightly after each palpal withdrawal, and he quieted her by rapid tapping with his fourth leg pair. On 7 August he died from her bite.

Geotrecha pinnata Emerton.

One male and three females were found running in an oak wood on 31 July and placed in a large cage. Two copulations were observed on that day and on the next respectively, the attitude being the same as in *G. crocata*. In the first case the male inserted his palpi each twice and successively from 5.42–5.43 P.M., then he turned away from the female, returned and inserted the right palpus for a few seconds, turned away, returned and inserted each palpus once, moved off, returned and inserted both once, then moved away from her again; but when he sought her again at 5.51 she had gone off. What is remarkable in this species is that the male, after one or two short palpal insertions, departs an inch or more from the female, stands still for a minute or more shaking his palpi, then turns and seeks her again (wholly by touch unaided by sight), the female generally waiting motionless for his return. He always mounts over her head. The next day the same male copulated in a similar fashion, from 11.35–11.44 A.M., with eight palpal insertions.

On 22 July five other individuals of this species were caught and placed in one large cage. Two were males, one of them lacked one palpus, and for convenience may be called A, while the other perfect individual we may call B; these males were combative on meeting each other, but not aggressive to the females nor these to one another. ♂ B at 5.20 P.M. met and copulated with a gravid female, inserting his palpi about four times; then ♂ A touched her, she at first repulsed him but half minute later accepted two palpal insertions from him; at 5.36 both males were an inch away from her. Between 5.37 and 5.50 she received both males in the following order: ♂ A, ♂ A, ♂ B, ♂ A, ♂ B, ♂ B, ♂ B, ♂ A, ♂ A. Then she rose and moved away, returned to the same place, and repulsed further advances. After cleansing herself she began at 7.20 P.M. to spin her cocoon. Between 8 and 9 P.M. she was interrupted by ♂ A five times, but drove him off each time. At 9.06 ♂ B found her and copulated, and between then and 9.15 copulated eight times. Between 9.22 and 9.35 ♂ A made five advances, but was driven away each time. ♂ B copulated twice at 9.42, and at 9.44 she repulsed ♂ A. I then kept both males away from her in order to see the cocooning. This is a very remarkable case of a female accepting copulation from two males alternately;

and of interruption of the cocooning process by such mating. Only an hour and a quarter after the last copulation she oviposited. During the cocooning she was aggressive, raising her fore-legs, but ♂ B pressed them down by rapid tapping and mounted over her head; the mating was forced upon her against her maternal instinct.

Prosthesima atra (Hentz).

One male and four females were caught 7 August and placed in a large dish, all unable to walk on the vertical glass side. On 9 August the male was seen in mating attitute, but without palpal insertion, for a quarter of an hour; this was at 5.20 P.M., and at 6.55 he was again motionless upon a female, but without insertion of the palpi. Could it have been that he was waiting for her to moult? On 15 August a copulation was observed, the attitude as in *Geotrecha;* the pair was first seen at 8.40 P.M. (they were not in copula a quarter of an hour before), and during the succeeding 19 minutes he inserted his left palpus 4 times and his right 3 times, each insertion lasting from 1 to 2 minutes. Another copulation was seen on 20 August at noon.

Misumena aleatoria (Hentz).

The male of this Thomisid is many times smaller than the female. A pair were placed together in a cage on 27 August. In the copulation both palpi are inserted simultaneously, and the male is placed upon the ventral surface of the abdomen of the female with his head pointed in the same direction as hers; the ventral surfaces of the two are apposed. The male, after discharge of the sperm, may remain upon the female's venter or may climb to her dorsum. He continues to hold to the female for astonishingly long periods, for he is so small and nimble that she is unable to displace him. Thus at one time he remained upon her for 22 hours, even though I disturbed them by removal to a bottle, and I found it difficult to push him off with a pin; at another time he remained continuously upon her from 4.57 P.M., 30 August, until 7.30 A. M., 1 September, when he left her, but regained her at 9 A.M. and remained upon her until the following morning, when she was found dead. Even her walking around the cage did not seem to disturb him. Palpal insertions occupied only a small part of these periods.

Xysticus nervosus Banks.

Two adult males and an immature female were placed in one cage on 5 September. She repulsed their advances, and after moulting on 11 September, was placed again with the males. One male found and embraced her, then the other drove him off, or the first left the

female to fight the other male, and this fighting of the two males upon and around her body continued for half an hour, when I separated them. The next day the same fight was renewed over her motionless body for 50 minutes, when the female rose and walked away, the males, thereafter, avoiding her. The copulatory attitude is like that of *X. stomachosus*, previously described by me (1903). The males appeared as eager to fight as to mate.

Ceratinopsis interpres Em.

Two males and a female of this small theridiid were placed in a vial on 12 July. The males were savage on meeting and grappled with each other. Within a few minutes the three had spun a maze of lines. Twice it happened that both males simultaneously seized and tried to embrace the female, and once one male copulated while the other endeavored to do so; in each case the female shook both off at the end of a minute or two. Finally one male inserted both palpi continuously for 21 minutes; their heads were in the same direction and ventral surfaces apposed, the male held her with his first two pairs of legs and had his head a little posterior to her epigynum.

7. Nesting and Cocooning.

The architectural habits of *Ariadna* and *Pisaurina* have been described above.

Phidippus purpuratus K.

We have mentioned that during June a male and female are frequently found together in one nest, and such mating nests are well known for the Attids; these are perhaps the same as the nests which the females occupy during the Winter. But on bringing home such pairs and placing them in cages no such mating nests were made, but the male and the female each built a thin-walled nest with two apertures, during which they remain mostly only at night; the two would also use the nests interchangeably, and would usually copulate outside of them. Before cocooning each of my captive females spun in an angle of the cage a much larger, entirely closed nest, so thick-walled that she can scarcely be seen through it, and within this spun all the cocoons of one season. Whether under natural conditions, on the lower side of a stone, the female would employ her mating-nest as a cocoon-nest, or whether the two are separate structures, I have not ascertained. The male may enter the cocoon-nest after the female has made an opening to it, to copulate with her, but he never remains long therein, but usually spins a smaller nest of his own on its outer

surface. The special cases observed of cocoon-nest construction, and of cocooning, were the following. ♀ 1519 made a thin nest on 28 June, and during the night made it very thick-walled with a narrow aperture at one end. On the following day she was found at 12.30 P.M. spinning vigorously across a vertical circular area, of greater diameter than her own length, of the inner surface of the nest; this was a distinct cocoon-base made upon the wall of the nest. She ceased suddenly at 1.10, rested quietly until I left at 1.30, and on my return at 2.50 was again spinning on the circular base, and worked through the afternoon. At 8.10 P.M. she oviposited upon the base, holding her head down and her feet on the margin of the base. She remained quiet until 8.32, when she began to spin the cover for the eggs, swinging the spinnerets from side to side and revolving her position from time to time; this cover-spinning continued to the next day after 7 A.M. On the 30 June she left the nest for the first time, from 8 July on left the nest daily to hunt for food and made a second aperture for egress. The young began to leave the nest on 15 August, and at that time I found a second cocoon containing eggs within the nest (the young of which hatched 12 September). ♀ 1521 laid a mass of eggs within a thin-walled nest on 2 July, but she ate them. On the 26 and 27 July she worked continuously spinning a perfectly closed cocoon-nest in an upper corner of the cage, then from 3 P.M. on for three hours spun a cocoon-base within it, this base spun in an oblique position and its diameter somewhat less than her own body length. She oviposited about 9 P.M. (during my absence). Next morning at 8.00 she was spinning a cover, but it was still very thin; consequently there must have been a long pause between the oviposition and cover-spinning. She did not leave the nest until fourteen days later; and when I opened the nest on 12 September it contained hatched young. ♀ 1525 was found on 17 July spinning a cocoon-base within an entirely closed, thick nest from 3–5 P.M.; this base was vertically inclined, extending from the floor to the roof of the nest, not against its side. She rested quietly for an hour and a quarter, spun again on the base for ten minutes, then occupied eleven minutes in oviposition. Then she seemed exhausted, and not until 10.34 began the cover-making, which was completed next morning. She did not leave the nest until seven days later. On 26 August she had again closed the nest, probably to make another cocoon. On opening the nest 12 September I found that only two eggs of the first cocoon had hatched, and none of the second.

These cases are given somewhat in detail, for they illustrate a considerable range of individual difference. The cocoon-nests are viscid

and very thick-walled, excellent homes for the young; the mother closes them tightly before making each cocoon, and generally does not emerge for food until a lapse of several days or even a fortnight; she always returns to them after her hunts, and remains there with the young until they leave. It is quite probable the young of the second cocoon, when it is made late in the summer, may overwinter in the nest.

Emerton says of this species (under the name of *mystaceus*):[11] "The largest of the New England Attidæ . . . . It lives under stones at all seasons. In winter or when moulting or laying eggs it hides in a thick white bag of silk, in which the cocoons are made early in the summer. The young become nearly full grown before winter."

Drassus neglectus (Keys).

These spiders, as Emerton has noted, are to be found in pairs in silken bags, and the following observations would show that such mating-nests are probably always spun by the males. A pair (♂ 1506, ♀ 1507) were taken from a nest on 16 June and placed in a cage. During that afternoon and evening he spun a thin, closed nest around them both, next day copulated within it, and both remained in the nest until their escape twelve days later. Another pair, ♂ 1510, ♀ 1511, from separate nests were put into one cage, and the male alone did the spinning of the nest. Another pair, ♂ 1527, ♀ 1528, were taken from one nest and placed in a cage; he built a beautiful and spacious saccular nest, entirely closed, in which he charged his palps with sperm and she moulted; she ate him in it three days later. Still a fourth male, of another pair (♂ 1529, ♀ 1530) from one nest, spun a mating nest. In only one case have I seen the cocooning, though several individuals were kept under observation. ♀ 1530 was on 24 July within a cylindrical closed nest, which was her enlargement of the mating nest constructed by ♂ 1529; in this species, then, the mating-nest may become the cocoon-nest. At 7.30 A.M. I found she was spinning within the nest upon a cocoon-base, that was a horizontally placed, slightly concave saucer of silk fastened by two opposed edges to the sides of the nest; the beginning of this base was not seen, but it must be either a modified partition of the nest or else a separate structure, and in either case not a part of the wall of the nest. I was unfortunately obliged to leave before the egg-laying, and on returning at noon found the cocoon was completed. The cocoon is always large, snow white, of a flattened biconvex shape, its circumference polygonal; the mother holds it tenaciously with her feet until the

[11] New England Spiders of the Family Attidæ, *Trans. Connecticut Acad. Sci.*, 8, 1891.

young emerge, though she may carry it about within the nest. In no case have I seen the mothers with cocoons taking food before the young hatch; the nest is kept closed through this period, and the spiders pay little attention to insects moving on its outer surface.

Geotrecha.

G. crocota and *G. pinnata* were not observed to make any nests in confinement, while *G. bivittata* constructs a very thin, small saccular nest. The conclusion of the cocooning was described by me (1903) for *G.* (*Thargalia*) *bivittata*, and this summer I have seen the act several times in the case of *G. pinnata*, and as follows: The cocoons are discoidal, excessively flattened and scale-like, their free surface (cover) very tough in consistency and difficult to tear open; under natural conditions they are spun against a stone, while all of the six cocoons made in my glass cages were placed at the junction of the floor and the side; thus they were circular discs bent in the middle at a right angle. ♀ 1566 on 22 July began spinning a cocoon-base at 7.20 P.M. She spun slowly, sweeping the spinnerets from side to side, over an area of about one and a half times her body length, at the junction of the wall and the floor, so that half the base was horizontal and half vertical. Half an hour later her labor had accomplished a ring of pearly silk, most beautiful to behold, slightly elevated and with almost no silk in the enclosed space. At 8.35 she began spinning rapidly on this central space, then from 8.55–9.45 she was repeatedly interrupted by the males A and B (as previously described) At 10.45 she ceased to sweep her spinnerets across the base, and instead raised and lowered them in applying silk near the middle of the disc, at the same time swaying her body backward and forward, thus producing a central cushion of softer texture. After each spinneret application the abdominal apex was elevated to a height equal to about two-thirds the length of her cephalothorax, then the spinnerets again applied. She ceased this abruptly at 10.57, stood over the centre of the base, discharged from her genital aperture a clear globule of viscid fluid upon it, and in this discharged in succession 8 large yellow eggs, this whole oviposition occupying two and a half minutes. But she attempted in vain to liberate herself from the viscid drop, and began to eat the eggs; this miscarriage may have been due to the late copulation. In the case of another individual (♀ 1572) the work on the cocoon base lasted from 9.45–10.57 P.M., the oviposition for a minute and a half, and the cover-spinning from 11.00 P.M. to after 12.45 A.M., when I left for weariness. The first ten minutes of the cover-making were occupied in carrying thread from the edge of the

base on to and across the egg mass, with swinging of the abdomen from side to side; the remainder of the time in brushing the spinnerets to and fro without raising them, which resulted in the dense structure of the outer surface of the cover. Next morning the cocoon was partly covered with small débris (bits of earth and wood, fragments of insects), and rendered much less conspicuous. The free surface of the cocoon is always furnished in this manner; it is never enclosed in a nest, and the mother does not remain by it. The cocoon is not only partially hidden in this way, but it is so closely adherent, so flattened and so tough, that the eggs are most excellently protected, and this explains why so few eggs are laid. Two cocoons were found with 8 eggs each, and three with 9. The method of applying the foreign objects to the cocoon was seen clearly in the case of two cocoons made by other females during the night of 26 July, some time between 10.30 P.M. and 7.30 A.M. These cocoons were placed only an inch apart, the mothers did not seem to distinguish their own from the other's, and proceeded to furnish either impartially. Each mother hunted around the cage by touch, for small objects, carried them in the chelicera to a cocoon, also found by touch (though there appeared to be some memory of its situation), then dropped them upon a cocoon. Then the mothers chewed these objects into smaller particles, and agglutinated them to the cocoon evidently by some salivary secretion, and to this secretion is also probably due the change in color of the cocoon surface from a beautiful opaline, or pearly, lustre to a dull brown.

So far as I know this is the first instance described of the application of some salivary secretion to the cocoon surface; very likely the bluish or greenish colors of the outer layer of Lycosid cocoons are also due to a similar secretion from the mouth, for the silk employed is white, and the cocoon does not change its white color until the mother holds it beneath her and carefully applies her mouth parts to all of its surface. This secretion may have the value of a varnish, a finish smoothing over all irregularities.

Phrurolithus alarius (Hentz).

As Emerton (1889) notes, this drassid "lives on and under stones in dry, open ground and runs with great swiftness short distances at a time." The spiders are much less frequently seen than their cocoons. The latter are tightly fastened to stones, scarlet in color, probably due to a salivary secretion, much flattened and scale-like, of greater diameter than the spider's length, and are sometimes covered with foreign matter. They are not guarded by the mother, and it was only

by keeping these spiders in cages that the makers of these cocoons were determined. One cocoon that I opened contained only 13 eggs.

Prosthesima atra (Hentz).

These common drassids live beneath stones in small, thin-walled nests. A remarkable habit was seen on several occasions during the nest-making in cages: the spider spins first upon the floor of the cage beneath her, then at intervals stands nearly vertical with the head down rotating the elevated abdomen on its pedicel, or else bending it quickly from side to side; the abdominal apex then describes circles in the air with the spinnerets actively moving. This is done for a few seconds at a time, and alternated irregularly with spinning on the floor. Such an attitude has not been seen by me before. Is it an attempt to find some roofing object against which to spin, or is it a throwing or casting of a line? Emerton (*l. c.*) has observed that the "cocoon is flat on one side, by which it is attached, and convex on the other. It is white, or sometimes a little pink." The cocoon is sometimes, but not always, thinly covered with foreign particles, and is guarded by the mother, who rests upon it; but she does not hold it nearly so tenaciously as *Drassus* does. Wild cocoons are found first in the early part of August, and sometimes two are found superimposed.

Poecilochroa.

A female of *P. variegata* (Hentz) was placed in a vial, where she made an incomplete nest at one end. On 27 July at 7.30 A.M. she was standing in a small cell within this nest upon a nearly completed cocoon-base; this base was thin, roughly circular in outline, its diameter about one and a half times her body length, and placed almost vertical, with its margins fastened to the inner wall of the nest. She oviposited upon the centre of this base from 8.02 to 8.04, then spun until 9.15 constructing the cover. Until 1 September, when the young emerged, the cocoon remained in the same position, attached by its edges to the nest, with the mother holding it continuously. A female of *P. bilineata* (Hentz) was caught on 11 July, and on the night of 13 July made a cocoon: a flattened circular disc, placed horizontally, its diameter greater than her length with outstretched legs, its color glistening ivory-white with a pearly lustre. She subsequently made a closed nest around it, did not change its position, but remained upon it; she left the nest for the first time four weeks later, but returned to it; the young hatched 17 August. A wild cocoon of this species contained 22 eggs.

Range of Architecture in Drassids.—The observations just described

show an interesting series: *Pœcilochroa*, which leaves the cocoon attached to the nest and holds it until hatching; *Drassus*, which cuts loose the cocoon from the nest wall, but which also holds the cocoon continuously until hatching; *Prosthesima*, which makes a much thinner nest and holds the cocoon within it, but not tenaciously, and occasionally places foreign objects on its surface; and *Geotrecha*, which makes only a very slight nest (*bivittata*) or no nest at all (*pinnata*), and which does not guard the cocoon, but regularly garnishes it with foreign matter. The last condition is probably the most modified, for it represents the loss of the maternal instinct. At the end of this series the number of eggs is least.